Numerical Modeling of Acoustic Propagation
In a Variable Shallow Water Waveguide

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LONG-TERM GOALS

Random variability in shallow water will induce variability in a propagating acoustic field. The long-term goal of this research is to quantify how random variability in the ocean environment translates into random variability in the acoustic field and the associated signal processing algorithms. Particular emphasis is placed on the effects of time-varying shallow water internal waves.

OBJECTIVES

One objective of the current work was to calculate how shallow water internal waves would affect the so-called "wavguide invariant." The concept of a waveguide invariant was popularized by Brekhovskikh and Lysanov [1991]. They showed how contour plots of acoustic intensity, mapped in range and frequency, would exhibit striations. They defined a parameter "beta" as a simple function of range, frequency and the slope of the striations, and claimed that this parameter was an invariant. They cautioned, however, that this simple formulation was valid only for certain groups of modes. Under previous support, an incoherent signal processing algorithm was developed. The output of the processing algorithm was an estimate for the distribution of possible values for the waveguide invariant. The algorithm was based on spectral analysis and could be used to study the effects of medium variability.

APPROACH

The approach is to first test the signal processing algorithm on synthetic data generated using the parabolic equation method. The ocean environment was allowed to change consistent with internal wave activity. The waveguide invariant distribution was tracked as the internal wave field evolved. Analytical expressions for the signal processing output were then developed and compared to the numerical simulations.

WORK COMPLETED

Under previous support, we derived an expression for the waveguide invariant distribution in terms of the acoustic modes for the special case of a range-independent environment. This permitted efficient parameter studies. Quantities such as source and/or receiver depth or bottom loss could be varied at

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negligible computational cost. The results were documented in a book chapter [Rouseff and Spindel, 2002].

Under current support, which began four months ago, the classic work on stochastic acoustic mode coupling developed by Dozier and Tappert [1978] was adapted for propagation through a realistic shallow water internal wave fields. To model the internal waves, the formulation developed by Henyey et al. [1997] was applied to data taken during the 1996 Coastal Mixing and Optics/Volume Scattering Experiment [Williams et al., 2000]. Both the second- and fourth-moments of the acoustic mode amplitudes were calculated. Presently, we are adapting these calculations to predict the statistical moments of the random waveguide invariant distribution.

RESULTS

Figures 1 and 2 show sample calculations illustrating the mode coupling induced by shallow water internal waves. In the simulation, the water depth is 70 m and the bottom is typical of sand. The frequency is 240 Hz. The background sound speed profile is typical of the summer.

In both figures, the starting field consists of a single acoustic mode. In Figure 1, the starting field is the first acoustic mode, in Figure 2 it is the third mode. Shown is the mean intensity of the first seven acoustic modes as a function of range. The dashed lines show what would be modal intensity in the absence of internal wave induced mode coupling; the decay in range is due only to bottom loss. The figures show evidence of significant mode coupling. In Figure 2, at range 20 km the mean intensity of mode 3 is less than that of mode 2 even though at the source all the energy was in the former.

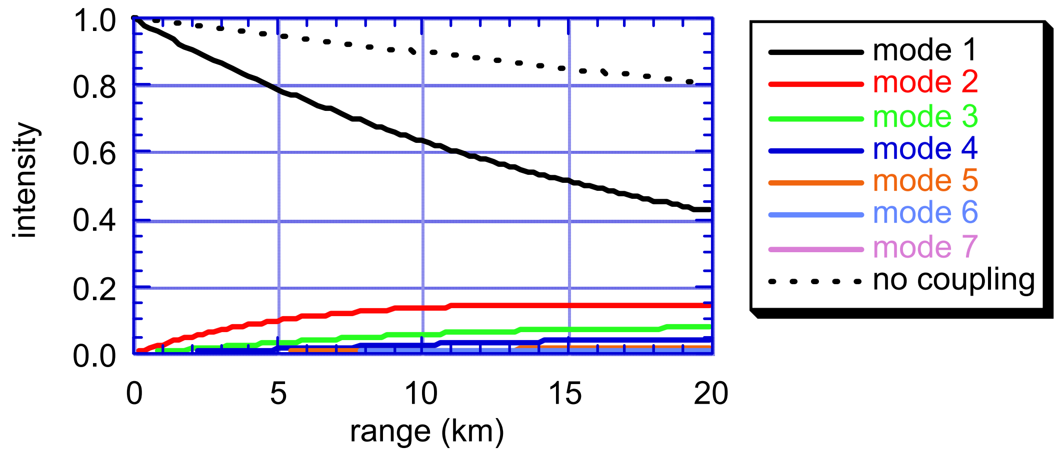

Figure 1. Mean intensity of acoustic modes propagating through shallow water internal waves. Single mode starting field, mode one. Dashed line shows attenuation that would occur with no internal waves. Plot shows significant coupling into other acoustic modes

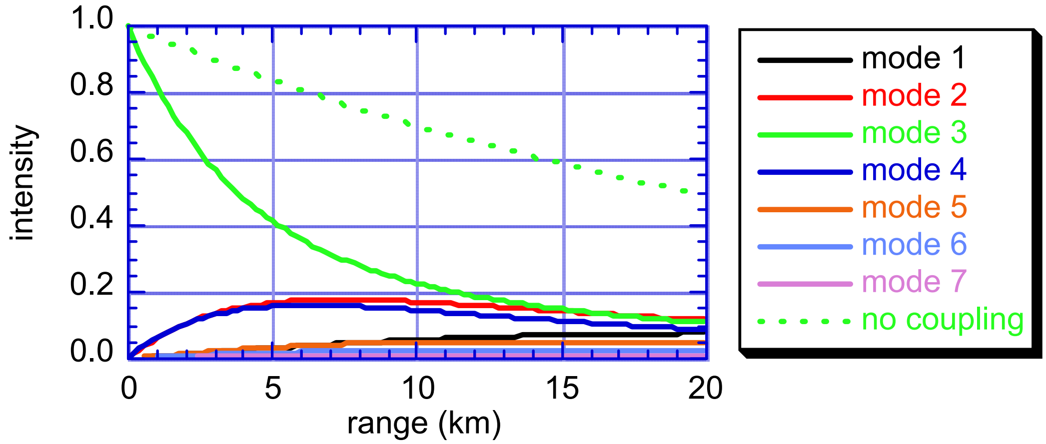

Figure 2. Mean intensity of acoustic modes propagating through shallow water internal waves. Single mode starting field, mode three. Dashed line shows attenuation that would occur with no internal waves. Plot shows significant coupling into other acoustic modes

IMPACT/APPLICATIONS

The concept of a waveguide invariant has enormous appeal. When valid, it says that the interference structure of the acoustic field can be largely characterized by a single scalar parameter. This parameter accounts for the dispersion properties of what could be a very complicated propagation environment. The present work will quantify how environmental variability such as from internal waves will affect the invariant.

TRANSITIONS

Our goal is to test the processing algorithm on field data and compare results to predictions. To date, we have acquired one data set and are in discussions to acquire more.

RELATED PROJECTS

Various aspects of the waveguide invariant are being studied by investigators at Scripps, MIT, NRL, Orincon and Neptune Sciences.

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